The Simulations Team for the ACT Vision Mission Study

The ACT Vision Mission Study Simulation Effort

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Abstract

The Advanced Compton Telescope (ACT) has been selected by NASA for a one-year "Vision Mission" study. The main goal of this study is to determine feasible instrument configurations to achieve ACT's sensitivity requirements, and to give recommendations for technology development. Space-based instruments operating in the energy range of nuclear lines are subject to complex backgrounds generated by cosmic-ray interactions and diffuse gamma rays; typically measurements are significantly background-dominated. Therefore accurate, detailed simulations of the background induced in different ACT configurations, and exploration of event selection and reconstruction techniques for reducing these backgrounds, are crucial to determining both the capabilities of a given instrument configuration and the technology enhancements that would result in the most significant performance improvements.

The ACT Simulation team has assembled a complete suite of tools that allows the generation of particle backgrounds for a given orbit (based on CREME96), their propagation through any instrument and spacecraft geometry (using MGGPOD) - including delayed photon emission from instrument activation - as well as the event selection and reconstruction of Compton-scatter events in the given detectors (MEGAlib). The package can deal with polarized photon beams as well as e.g. anticoincidence shields. We report here on the suite of tools used in the ACT Simulation effort.

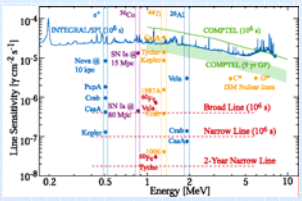
We thank NASA for support of this research.

The Advanced Compton Telescope (ACT)

ACT's main goal:

"to uncover how supernovae and other stellar explosions work to create the elements"

Measure 847 keV line from 5 SNIa @ 15σ per year, at E/ΔE > 100 (corresponding to 50 SNIa detections per year)



Instrument Requirement Target

- 847 keV broad-line (3%) sensitivity of ~ 7·10-7 ph/(cm²s) (for point sources)
- Energy resolution E/ΔE > 100
- additional requirements, including a π to 2π field-of-view, driven by secondary science goals

→ See Talk by S. Boggs

Requirements for an ACT Mission Study Simulation Suite

- Complete and faithful representation of space environment components
- Realistic modeling of induced instrumental backgrounds, including activation
- Flexible instrument design represented in simulation mass model with comparable detail
- Event selection and event reconstruction algorithms capable of demonstrating the potential of these techniques for ACT

Modeling of Radiation Effects – MGGPOD

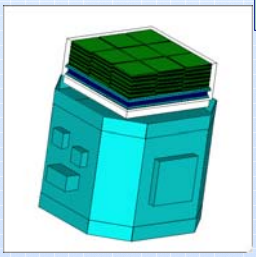
(http://sigma-2.cesr.fr/spi/MGGPOD/)

- Suite of Monte-Carlo codes built around CERN's GEANT3 package
- Originally intended for INTEGRAL/SPI background simulation
- Simulates physical processes relevant to the generation of instrumental backgrounds at low and intermediate γ-ray energies (50 keV to several MeV for ACT), including
  - Neutron transport and activation
  - Build-up and decay of radioactive isotopes
  - Prompt de-excitation of excited nuclei
- Performance proven in background models for TGRS, SPI, and RHESSI
- For ACT, additional input particle geometries and more detailed event output had to be added; the core simulation code remained unchanged
- MGGPOD [7] also comprises the GLECS and GLEPS [6] packages for simulating the detailed effects of atomic binding and polarization on photon scattering processes

Space Environment

- Accurate space environment model inputs are crucial to accurate instrument background predictions
- Background component input spectra in MGGPOD format generated
- based on the CREME96 package [2] and measured background component spectra
  - CREME96 is widely used for satellite electronics design requirements. CREME96 has been shown accurate at predicting galactic cosmic ray (CR), anomalous CR, and solar flare components of near-earth environment [3]. It includes a well tested geomagnetic transmission calculation algorithm.
  - ACT cosmic-ray proton and trapped proton (AP8 model) fluxes directly from CREME96.
  - CR e^- and e^+: [5] and [9] with CREME96 geomagnetic transmission
  - Neutron environment based on [4] and references therein
  - Cosmic diffuse photon based on analytical models by [5]
  - Albedo photons based on [5] and Compton balloon data

Flexible Mass Model

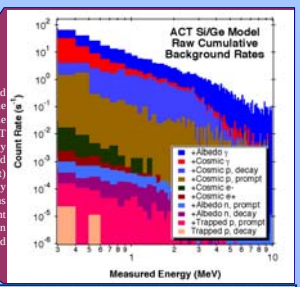


- Universal mass model generation tool
- Different detector and structural materials easily supported
- Common simulation baseline S/C bus based loosely on the GLAST bus

- Using this common Mass Model Generator facilitates comparisons of performance simulations for different detector concepts, including "hybrids" composed of several different detector materials/technologies
- The above figure shows the baseline ACT mass model used in our first round of end-to-end software tests. It represents the Si-Ge hybrid configuration studied at ISAL

Realistic Model of ACT Instrumental Background and Response as Basis for Accurate Prediction of Instrument Sensitivity : The Simulated Measurement Data

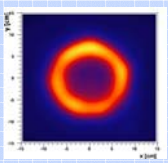
Background induced in the initial baseline Si-Ge ACT instrument (by background component) before any event selections or event reconstruction are applied



Flexible and Detailed Event Selection and Event Reconstruction Software – the MEGAlib package

- Originally developed for data analysis of the MEGA prototype, a German-developed Compton telescope consisting of a thin Si tracker and a CsI calorimeter [8]
- Package consists of several programs containing the complete data analysis chain for Compton Telescopes, from discretizing simulation data up to high-level data analysis, i.e. image reconstruction, background estimation, and polarization analysis
- Event reconstruction is the most critical step – it determines how well background events and source counts can be separated
- Different approaches implemented or under development, the most promising is based on Bayesian statistics – a 7-D data space is used to determine the direction of motion and to qualify each event

→ See Poster by A. Zoglauer



The Figure shows a MEGAlib-based reconstruction of an extended (ring-shaped) laboratory source using MEGA prototype data. This figure nicely illustrates the capabilities of the MEGAlib algorithms up to image reconstruction. A correct reconstruction of the incident direction and energy of measured photons is required for this image of the ring to emerge; the irregularities are due to hardware imperfections not fully represented in the image reconstruction software. For details see [8].

Based on the number of background events remaining – and the effective area of the given instrument under study – the ACT Simulation suite allows us to predict a given ACT 'version's' broad line sensitivity for the orbital parameters selected

ACT Simulation Status and Outlook

- ACT simulation pipeline working at multiple sites for several months
- Building on long-standing well-tested software packages (geant, ..)
- Easy to use, all stages can easily be modified
- Environment model tool verified through comparison with SPENVIS/SIREST LEO models for RHESSI and published data

- Improvements and enhancements of the event selection and event reconstruction algorithms are ongoing efforts that constitute(d) a large portion of the ACT Vision Mission Study task
- Optimum event selections and the set of event reconstruction tools necessary depend on the ACT configuration under study
- The ACT Simulation Suite constitutes a valuable tool for gamma-ray astronomy instrument design in general

References

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